
SIMULATIVE ANALYSIS OF CHANNEL AND QoS AWARE SCHEDULER TO ENHANCE THE CAPACITY OF MULTIMEDIA LTE NETWORKS

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ABSTRACT

Here a new MAC scheduling mechanism for the downlink of LTE systems named Channel and QoS Aware Scheduler is analyzed. This scheduler is based on a Channel and QoS aware algorithm which performs joint time and frequency scheduling. The relevance of the scheduler comes in to play in a situation in which the number of data hungry users are at the rising edge and they demand for traffics that have very tight QoS requirement in terms of bit rate and delay. eg:- VoIP, Video conferencing & Online Gaming. The performance of the scheduler is evaluated by means of network simulations in LTE single cell scenario with mixed traffic and compared the results with state of the art LTE downlink schedulers. The results shows that in a realistic scenario in which quality of channel varies over time as well as frequency, CQA scheduler significantly outperforms other schedulers in terms of provided QoS.

Keywords : Channel and QoS Aware Scheduler, LTE, Multimedia Traffic, Scheduling, Single Cell Networks

I. INTRODUCTION

For many years, voice calls dominated the traffic in mobile communication network. The growth of mobile data was initially slow, but in the past couple of years, its use started to increase dramatically. A part of this growth was driven by the increased availability of 3.5G communication technology. More important, however was the introduction of Apple iPhone in 2007, followed by devices based on Google's Android operating system from 2008. These smart phones were more attractive and user friendly than their predecessors and were designed to support the creation of application by third party developers. The result was an explosion in the number and use of mobile applications. As a contributory factor, network operators had tried to encourage the growth of mobile

data by introduction of flat rate charging schemes that permitted unlimited data downloads. That led to a situation where neither developers nor users were motivated to limit their data consumption.[1]. The addition of multimedia services such as Skype, GTalk, WhatsApp, multi-user interactive gaming etc in cellular communication systems has created new challenges for resource allocation, making it as one of the key component that affects the performance of an LTE system. Due to the higher traffic flows, the requirement of efficient resource allocation is more important in downlink than uplink. In short, we need an efficient and smart downlink packet scheduler in the eNB because it simply maintains the balance between the operator- customer equations. The operator wants to maximize revenue by utilizing its limited resources to the fullest to accommodate as many users as possible whereas the users need these applications to the top quality with minimum amount of interruption and delay.

The LTE systems can have simultaneous delivery of large amount of consumer multimedia content to vast number of wireless devices which increased its popularity worldwide. As a result there has been a growing interest in the design of LTE Packet Scheduling algorithms & in the recent scientific literature, several downlink packet scheduling algorithms have been proposed that focuses on different aspects of QoS. A very recent and vast survey on the topic is provided in [2]. However, most of the scheduling algorithms mentioned in this survey are not QoS aware. So they are not suitable for LTE systems. [2]

QoS-aware LTE downlink scheduling algorithms that are aiming at satisfying the delay requirement of real-time traffic, is proposed in [4]. Here the data flows are prioritized and will be scheduled based on the Head-of-line (HOL) delay parameter. A disadvantage of this approach is that it does not take into consideration the variable channel conditions; in particular, in realistic scenarios in which the presence of fast and frequency-selective fading is expected, assigning radio resources based only on the HOL metric often results in the selection of lower modulation and coding schemes, which is spectrally inefficient and thus does not allow to achieve a high capacity. [3]

Among the channel aware approaches, the Token Bank Fair Queue (TBFQ) scheduler can be considered. This is a queue and channel-aware scheduling algorithm which attempts to maintain fairness among users. TBFQ is based on the leaky bucket principle, and it is mainly designed to support bursty traffic. It assigns higher amount of resources to the users that have more data in the queues. This feature of the TBFQ approach is not adequate for voice traffic, since it is characterized by small packet sizes and low expected queue fill levels. Furthermore, TBFQ does not explicitly take into account the delay requirements. [5][3]

Another important downlink scheduler is the Priority Set Scheduler (PSS), which is a channel-aware scheduler that aims at guaranteeing a predefined bit rate to each user. This algorithm has a very good performance because it successfully combines TD and FD scheduling in order to achieve a higher spectral efficiency and increase the overall system capacity. The main drawback of this scheduler is that it only considers the Guaranteed Bit Rate (GBR) parameter specified within the EPS bearer. This means that delay sensitive classes of traffic, such as voice, video and gaming, may suffer poor quality even if their GBR requirement is satisfied. This limits the application of this scheduler to delay insensitive traffic. [6][3]

A step forward in this research line, [3] proposes a new LTE downlink scheduling algorithm called Channel and QoS Aware (CQA) scheduler. The QoS parameters that it considers are the HOL and the GBR parameters. The CQA scheduler performs the scheduling according to different criteria in the TD and FD, in order to achieve a high spectral efficiency while at the same time taking care of satisfying the delay requirements of the traffic. The disadvantage is that, only VoIP services are considered and the simulation scenario is limited to static and pedestrian which is far away from a realistic scenario. [3]

The CQA scheduler proposed in [3] is analyzed based on simulations in order to prove that the scheduler provides good performance in a realistic LTE scenario with multimedia traffic & results are compared with state of the art LTE downlink schedulers.

II. CHANNEL AND QoS AWARE (CQA) SCHEDULER

The CQA scheduler, as the name implies, is based on Channel and QoS aware algorithm, which performs joint TD and FD scheduling. This approach is more efficient than only TD or FD scheduling [7]. In the TD, at each TTI, the CQA scheduler selects from all the users $j = 1, \dots, N$ those that did not yet reached the maximum bit rate (MBR) and groups them by HOL delay calculating the metric m_{td} in the following way[3]:

$$m_{td}^j(t) = \lceil \frac{d_{HOL}^j(t)}{g} \rceil \quad (1)$$

Where $d_{HOL}^j(t)$ is the current value of HOL delay of flow j , and g is a grouping parameter that determines granularity of the groups, i.e. the number of the flows that will be considered in the FD scheduling iteration. The grouping is used to select the most urgent flows, i.e., with the highest value of HOL delay, and to enforce the scheduling mechanism to consider those flows in the following FD scheduling iteration. [3]

The groups of flows selected by TD iteration are then forwarded to FD scheduling starting from the flows with the highest value of the m_{td} metric until all RBGs are assigned in the corresponding TTI. In the FD, for each RBG $k = 1, \dots, K$, the CQA scheduler assigns the current RBG to the user j that has the maximum value of the FD metric which we define in the following way[3]:

$$m_{fd}^{(k,j)}(t) = d_{HOL}^j(t) \cdot m_{GBR}^j(t) \cdot m_{ca}^{k,j}(t) \quad (2)$$

where $m_{GBR}^j(t)$ is calculated as follows[3]:

$$m_{GBR}^j(t) = \frac{GBR^j}{\bar{R}^j(t)} = \frac{GBR^j}{(1-\alpha) \cdot \bar{R}^j(t-1) + \alpha \cdot r^j(t)} \quad (3)$$

where GBR^j is the bit rate specified in EPS bearer of the flow j , $\bar{R}^j(t)$ is the past averaged throughput that is calculated with a moving average, $r^j(t)$ is the throughput achieved at the time t , and α is a coefficient such that $0 \leq \alpha \leq 1$.

The purpose of $m_{ca}^{(k,j)}(t)$ is to add channel awareness to the system in order to maximize the capacity by assigning the resources to the flows that can use them more efficiently. For $m_{ca}^{(k,j)}(t)$ two different metrics are considered: $m_{pf}^{(k,j)}(t)$ and $m_{ff}^{(k,j)}(t)$. The m_{pf} is the Proportional Fair metrics which is defined as follows [3]:

$$m_{pf}^{(k,j)}(t) = \frac{R_e^{(k,j)}(t)}{\bar{R}^j(t)} \quad (4)$$

where $R_e^{(k,j)}(t)$ is the estimated achievable throughput of user j over RBG k calculated by the Adaptive Modulation and Coding (AMC) scheme that maps the channel quality indicator (CQI) value to the transport block size in bits. The m_{pf} metric is a good channel awareness metric since it aims at simultaneously achieving the fairness among flows and maximizing system capacity by prioritizing the users that have suffered lower channel quality and the users that have extremely good instantaneous channel quality; the CQA scheduler that uses this channel awareness metric is denoted

as CQA_{PF} . The other channel awareness metric is m_{ff} [6] and it represents the frequency selective fading gains over RBG k for user j and is calculated in the following way [3]:

$$m_{ff}^{(k,j)}(t) = \frac{CQI^{(k,j)}(t)}{\sum_{k=1}^K CQI(t)^{(k,j)}} \quad (5)$$

where $CQI^{(k,j)}(t)$ is the last reported CQI value from user j for the k^{th} RBG. This is considered as good channel awareness metric since it aims at increasing the overall system capacity by prioritizing users that can use available resources more efficiently. CQA scheduler that uses this channel awareness metric is denoted as CQA_{FF} . [3]

III. PERFORMANCE EVALUATION

1. DESCRIPTION OF THE SCENARIOS

To evaluate the response of the CQA scheduler on multimedia traffic, we have simulated a typical outdoor scenario in which N UE's are attached to a single eNB. Here, we have considered a single cell scenario and hence intercell interference is not considered. As per 3GPP specification [8], the fading scenario considered is Extended Vehicular A (EVA) model, in which the user moves with a velocity 60 km/h. The modeled traffic are: VoIP, video streaming, Downloads and Real time gaming. Schedulers used other than CQA are Round Robin (RR), Blind Equal Throughput (BET), Proportional Fair (PF) and Priority Set (PS) scheduler.

2. SIMULATION SET UP

We have used the LTE-EPC network simulator (LENA) [9] to carry out the performance evaluation. The four traffics (VoIP, Video, Gaming and Downloads) were introduced together in the scenario in order to analyze the response of scheduling algorithms under consideration. The strain in system was evaluated by increasing the number of UE's. It has been taken care to keep the ratio of different traffic users constant. The generic settings used in the simulation are listed in Table I.

TABLE I. SIMULATION GENERIC SETTINGS

Parameter	Value
Simulator	NS3
Bandwidth	5MHz
AMC	PiroEW2010
Path Loss Model	Friis propagation Loss model
Fading Model	Trace Fading Loss Model
Number of RBs	25
Transmission Power of eNB	30 dBm
Transmission Power of UE	23 dBm
Mobility model	Constant Position
Noise figure	eNB:5; UE:5
TTI	1 ms
Simulation Time (Per User)	10 seconds

The random generator used in placing the user equipments (UE) is based on a prior fashion for each iteration. Hence the result obtained with one parameter can be reliably compared with another. The simulation parameters are given in Table II. Output is taken with the support of flow monitor [10].

3. RESULTS

The performance of the CQA scheduler & the state of the art schedulers were evaluated in terms of QoS satisfaction. To measure the QoS satisfaction, we have evaluated the variation in average throughput when number of UE increases. Throughput is calculated as:

$$\text{Throughput } (T) = \frac{\text{Received Bytes} * 8}{\text{Simulation Period}} \text{ bps}$$

$$= \frac{\text{Received Bytes} * 8}{\text{Time at Last Packet Received} - \text{Time at First Packet Sent}} \text{ bps}$$

TABLE II. SIMULATION PARAMETERS

Parameters	Value	
Cell Architecture	Single Cell	
Number of eNB	1	
Number of UE	VoIP: 40%	10-100 varied in steps of 10
	Video:30%	
	Gaming:10%	
	Downloads:20%	
Fading scenario	Vehicular @ 60km/h	
Cell size	15 km	

Figure 1 shows the throughput analysis of single cell voice users in a mixed traffic scenario. Up to 60 users, CQA scheduler outperforms all other schedulers that are taken for comparison. The degraded performance beyond 60 users justifies the fact that classes of traffic that need more quality of service like video, gaming and download are getting more resources than voice traffic.

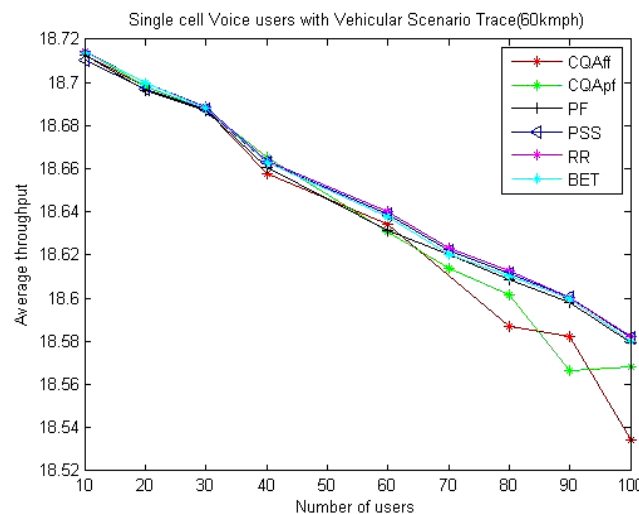


Figure 1: Throughput analysis of Single cell voice users in a mixed traffic with Vehicular scenario trace

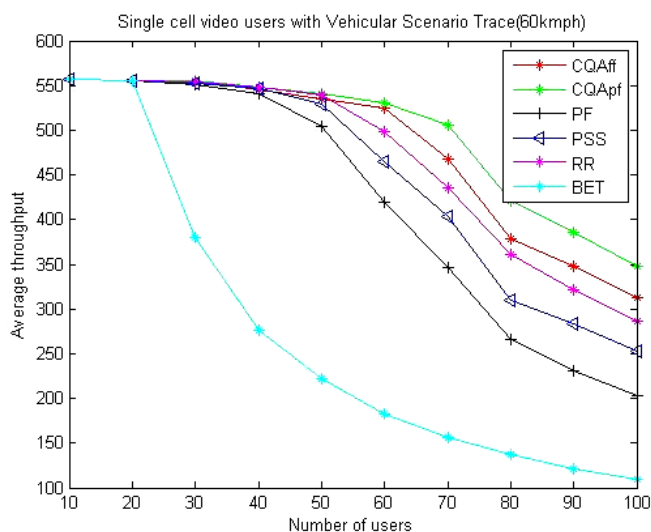


Figure 2: Throughput analysis of Single cell video users in a mixed traffic with Vehicular scenario trace

Throughput analysis of video users is given in Figure 2 and Figure 3 shows the throughput analysis of gaming users. In both the figures it is obvious that CQA scheduler yields the best performance. It should also be noted that beyond 60 users, the CQA scheduler yields far better performance than other schedulers. In other words, the gaming and the video users with CQA schedulers are getting more resources to meet their requirements in this mixed traffic scenario and hence proving the fact that classes of traffic with tight QoS requirement will be given more priority.

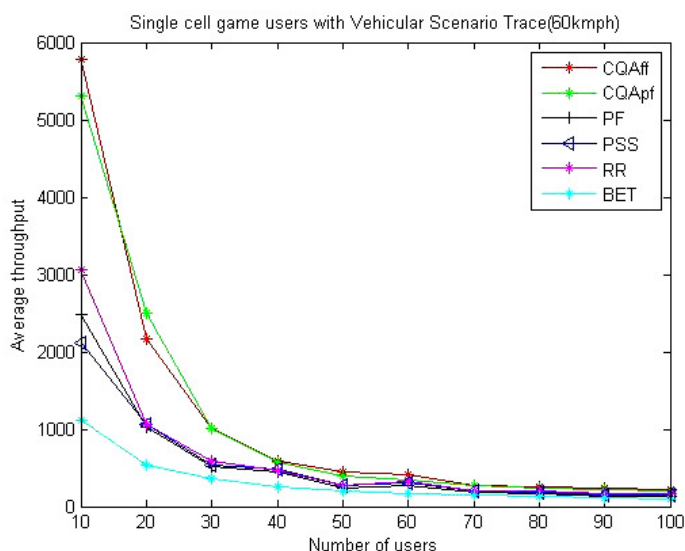


Figure 3: Throughput analysis of Single cell gaming users in a mixed traffic with Vehicular scenario trace

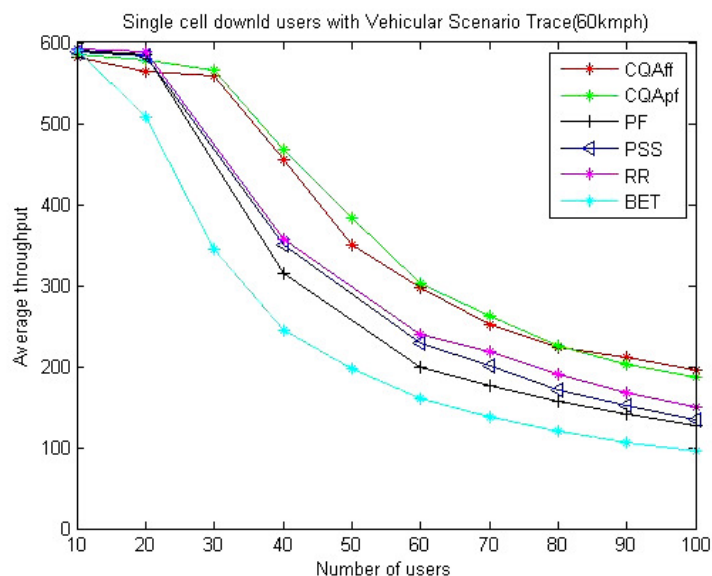


Figure 4: Throughput analysis of Single cell download users in a mixed traffic with Vehicular scenario trace

Figure 4 shows the throughput analysis of download users. Here CQA scheduler not only just outperforms other schedulers but also yields an excellent performance on comparison. For instance, for 50 users in the cell, the download users with other schedulers were getting maximum throughput of 300 bps whereas CQA_{pf} yields throughput more than 400 bps. It should also to be mentioned that beyond 60 users, the download users with CQA scheduler are getting more resources in comparison with other schedulers. This proves the fact that CQA scheduler is compactable in a situation in which there is a need to provide multimedia traffics to a large number of users with minimal interruption and delay and without compromising the quality of service.

In short the CQA scheduler outperforms all other schedulers when video, gaming and download traffic are considered. In the case of voice users, it gives comparatively degraded performance when numbers of users were more than 60 so as to cater for the tight QoS requirements of other traffics.

IV. CONCLUSION

Channel and QoS aware (CQA) scheduling algorithm is a novel scheduling algorithm that is both channel and QoS aware, which aims to enhance the LTE capacity. Here, the performance evaluation of CQA scheduler is carried out by means of network simulations in a realistic LTE scenario and the results are compared with other LTE downlink schedulers. Through analysis of the results thus obtained we can conclude that, in realistic scenarios in which the channel quality varies over time and frequency, the CQA scheduler significantly outperforms the state of the art solutions in terms of provided QoS and system capacity. Hence, in a commercial LTE network, where the balancing of operator -customer equations are of at most importance there is no doubt that the CQA scheduler will come in handy. There awaits a world with data hungry users and this algorithm is proven to serve for them.

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